Positive-Column Striations in Gaseous Conductors

by

B. E. Dobratz

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ELECTRONICS RESEARCH LABORATORY

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Electronics Research Laboratory
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ABSTRACT

The positive column in certain gaseous conductors was examined by external electrostatic probe pickup, by photoelectric signal pickup, and by rotating mirror images for time-periodic oscillations and space-periodic striations. Mercury vapor with dc excitation gave moving positive striations (motion away from anode) of large amplitude with a velocity of about 50 meter per second. No direct observational evidence of negative striations was found, contrary to what has been reported by some authors, but there was some indirect evidence of weak negative striations. No stationary striation pattern was found in mercury vapor with dc excitation. Mercury vapor with ac excitation gave pronounced stationary striations, which were found to be the optical result of cyclic motion of a sequence of moving positive striations. Ultrapure hydrogen and helium were examined. No oscillation or striation phenomena were found in these gases with the exception of a pronounced stationary striation pattern in ultrapure hydrogen under dc excitation.

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I. INTRODUCTION

This study was undertaken to examine periodic phenomena in low density gaseous plasmas. Time-periodic phenomena are called oscillations, and space-periodic phenomena are called striations. Oscillations and striations may be present independently if the striations are stationary and the applied voltage is dc, or they may be concurrent if the striations are moving.

Rotating mirror and oscillograph techniques were designed to check earlier reports of moving positive and negative striations (defined below). Also these methods were employed to examine stationary striations reported in ac operated devices.

A high vacuum tube was constructed with heated nickel and quartz diffusion leaks to allow the use of ultrapure hydrogen and helium, respectively. This was undertaken for the purpose of examining two gases other than the commonly used mercury-vapor and to attempt to answer the question of whether or not oscillations and striations occur in a pure gas.

Three types of striations are considered here: stationary striations with dc excitation, moving striations with dc excitation, and stationary striations with ac excitation.

The first type of striation has been observed quite early in the history of gaseous conductors.[1, 2, 3, 11] Some lengthy dispute between authors has occurred, however, on the question of whether or not these stationary striations occurred in pure gases or only in mixtures of gases. Several primary workers of this period[1, 2] employed chemical techniques to generate the "pure" gas and mechanical pumping schemes in a continuously-pumped vacuum system.

The first type of striation is characterized principally by its non-symmetric appearance. One side of the bright band is quite diffuse while the other is quite sharply bounded.

The second type of striation, the moving striation under dc excitation, was observed only a short time after the first type. Several early workers reported irregular striations sighted in a rotating mirror apparatus.[1] In 1923, Appleton and West made the initial attempt to link moving striations with electrical oscillations of the tube,[3] but no detailed theoretical connection between the two phenomena was offered until several workers reexamined the problem in the 1940's.[4,5] The theory evolved from this reexamination necessitated the concurrent existence of both a "negative" and a "positive" moving striation in the tube. The positive moving striation was defined as a space-periodic distribution of positive electrical charge moving from anode to cathode, and a negative striation was defined as a similar distribution of negative charge moving in the opposite direction. Opinion was split regarding the concurrent existence of both of these moving striations,[4,5,6,7] and to date the issue is not completely settled.

This study has found the concurrent existence of "positive" moving striations, electrical tube oscillations, and some indirect evidence for the "negative" moving striation. However, no direct evidence for the existence of the negative moving striation has been found.

The third type of striation, the stationary striation under ac discharge conditions, is a relatively recent observation,[8] and is characterized mainly by its perfect symmetry. At first, it was believed that this type of striation occurred at particular "resonant" frequencies of the gas tube,[8] but this study tends to indicate that this stationary striation occurs over several small continuous ranges of frequencies. Experimental evidence contained herein indicates that this type of striation may be considered as a special case of the second type where the direction of motion changes alternately.

It should be noted here that striations of types two and three have been found only in mercury-vapor and not in ultrapure hydrogen or helium, but that striations of type one have been found only in ultrapure hydrogen and not in helium or mercury-vapor. That is, no periodic phenomenon of any kind was found in ultrapure helium.

II. DEVICES TESTED

A. Mercury-Vapor Tubes

The mercury-vapor devices employed in this portion of the study were commercially available General Electric germicidal lamps of 5, 15, and 30 watt sizes. The dimensions of these tubes were I. D. 1/2", length 9 -1/4"; I . D. 7/8", length 14"; and I. D. 7/8", length 32", respectively.

All direct current data herein considered was taken with the filament in the cathode end of the tube heated.

The gas employed in these tubes may not have been pure mercury-vapor; however, other spectrum lines were not observed.

B. Pure Gas Tube

A sealed-off tube was constructed such that the conducting path was constrained to a straight tube approximately 36 inches in length from cathode to anode. The inside bore was approximately one inch. The anode was a hollow graphite structure while the cathode was an oxide-coated, heat-shielded, spiral-ribbon filament.

A Penning ion gauge was sealed to the tube for use as a combination vacuum gauge and ion pump.

Either pure helium or hydrogen could be admitted into the tube by means of a heated quartz diffusion leak and a heated nickel diffusion leak.

By sufficient use of the Penning ion gauge, pressure could be reduced in the system to a minimum of about 10^{-7} to 10^{-8} millimeters of mercury.

In all cases studied in this report, the tube was operated with a heated cathode. With all tubes tested the cathode power source was a lead-acid storage battery, and the anode power source was a very well filtered dc supply.[10]

C. Discussion

The mercury-vapor devices gave results much in line with results obtained by earlier investigators.[4,5,6,7] However, as is noted in greater detail below, no evidence to date of a substantial nature has been found to support the hypothesis of the existence of a negative striation.

The pure gas device when filled with hydrogen gave no evidence whatsoever of any type of moving striation. However, at pressures greater than a few microns of mercury, a very distinct stationary striation was noted. This immobile striation is sufficiently distinct and stable to be photographed quite easily. No oscillatory phenomena were noted in the anode voltage or phototube outputs while the stationary striations were very stable, and no moving striations were observable in a rotating mirror during this time. As noted below, some transient oscillatory phenomena were noted when the stationary striations became indistinct.

Contrary to a statement by Pilon,[9] no oscillatory phenomenon and no striated phenomena of any type were noted in ultrapure helium. The tube pressure was varied from about 3×10^{-4} millimeters of mercury to greater than 10 microns of mercury. In this pressure range and tube dimension, the helium conduction was unusually quiet.

III. STRIATIONS

A. Instrumentation for the Measurement of Striations

1. Photoelectric signal pickup

An optical pickup was devised with the circuit shown in Fig. 1. The photomultiplier was placed in a light-tight container with the only light entrance being through a pair of slits spaced an inch apart. Thus only a rather narrow portion of a tube could be examined at any one time.

The photoelectric pickup was mounted in a manner such that it could traverse a track mounted next to the tube, thereby maintaining a fixed distance from the tube while being movable along its length.

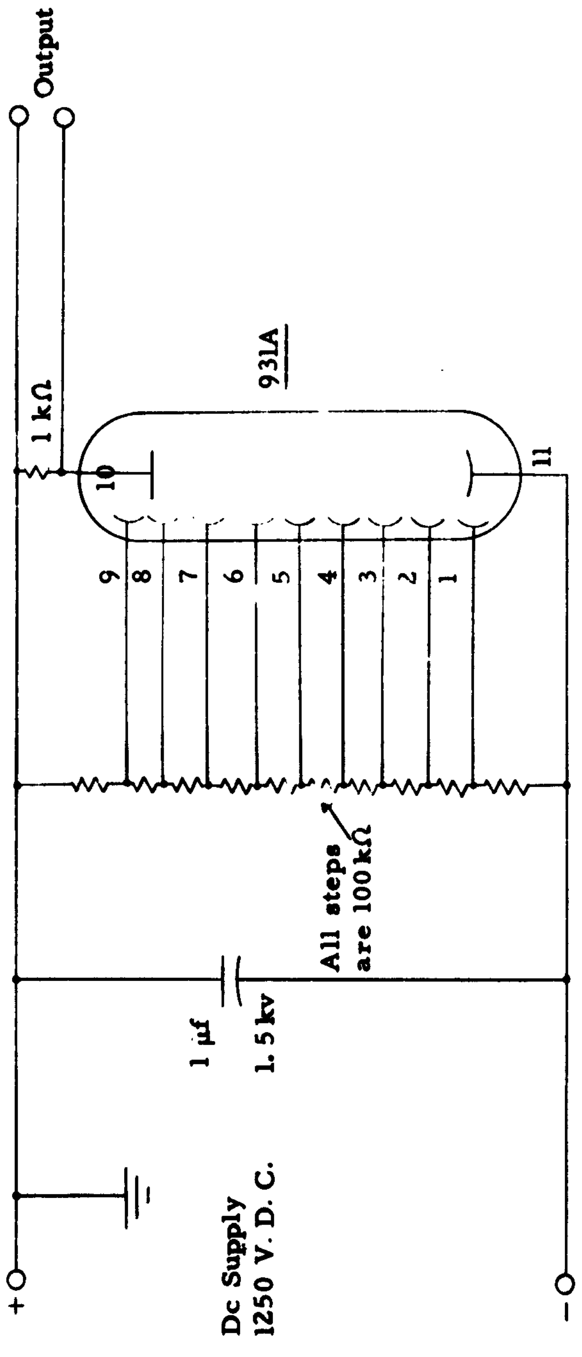

Fig. 1 Photomultiplier Circuit.

2. Rotating mirror

A rotating mirror was constructed by connecting a mirror holding apparatus directly to the shaft of a direct current motor. The dc motor allowed a continuous control of the mirror rotation velocity. Striation velocities up to several hundred meters per second could easily be measured by this method.

3. Oscillographic methods of striation velocity determination

Essentially two different methods of striation velocity measurement were made using the oscilloscope. First, a method using two electrostatic pickups on the surface of the tube was employed. See Fig. 2. For a negative striation, varying the distance L would yield data by which a velocity of motion could be computed. For any one tube tested in this series, a minimum distance over which L could vary was greater than 10 centimeters. Thus for a high sweep speed oscilloscope a change in the distance L should move a signal picked up a perceptible distance along the sweep time base. Reasonable accuracy of velocity measurement by this method could be expected up to approximately 5×10^4 meters/second.

Secondly, a method employed by Donahue and Dieke[4] was used. In this method, the oscilloscope was synchronized by a signal from the tube anode, and a signal from either an electrostatic pickup or the photoelectric pickup was fed to the oscilloscope vertical input. By moving the vertical input pickup along the tube a phase shift could be measured and hence the velocity.

The fundamental assumption in the the use of the latter method is that there is a one to one causal relationship between an anode signal and the striation phenomenon under examination. To date, no evidence contrary to this assumption has been found.

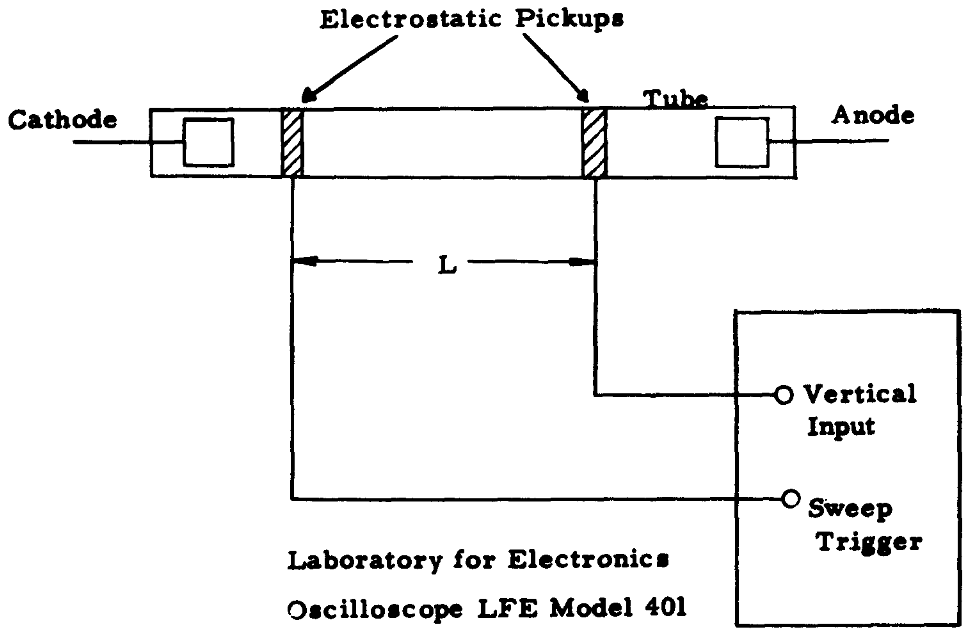

Fig. 2 Striation velocity measurement by oscillographic means.

It should be noted that the first oscillographic method mentioned above might result in some ambiguity. This would be the case if the strength of the electrostatic signals due to negative and positive striations passing a pickup were of approximately the same magnitude. In the second method, this would not be a problem since the oscilloscope is synchronized with the anode signal and since it is unlikely that the electrostatic signal of positive and negative striations would be identical.

B. Positive Striations

Let us define for present purposes a positive striation as any space-periodic disturbance which travels from the anode of the tube to the cathode, as if it were positively charged.

As reported by earlier workers,[4, 5, 6] the light output of the tube reaches a maximum as a positive striation passes the point of observation and falls nearly to zero between striations. This is clearly seen from the output of the photomultiplier or from the rotating mirror.

Both the rotating mirror and oscillographic phase shift measurements show the positive striation velocity to be on the order of 50 meters per second in mercury-vapor. There is a slight dependence of striation velocity on tube current for very low currents. However, for currents above 15 milliamperes in the mercury-vapor devices there is no regular dependence upon current. It is also noted that above 15 milliamperes operation is on the normal glow portion of the current-voltage characteristics curve where tube potential drop is essentially independent of the tube current.

Contrary to results reported by Donahue and Dieke,[4] striation velocity was observed to be approximately constant along the length of the tube. See Fig. 3. The band pattern observed in the rotating mirror appeared quite even with the individual striations presenting very straight bands. At low tube currents the rotating mirror revealed rather randomly irregular striation velocities, but no periodic irregularity as might be expected from reference 4.

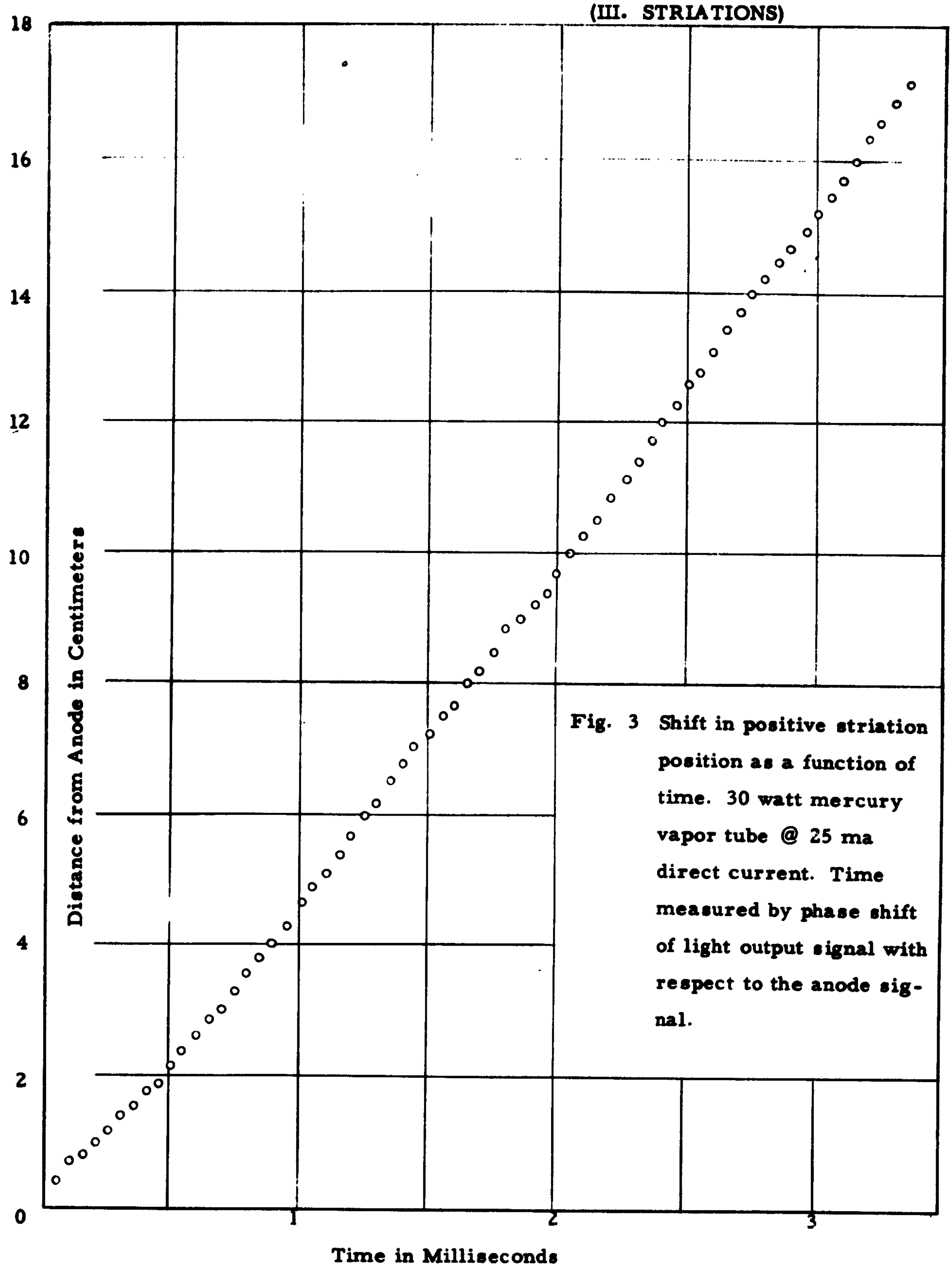

Fig. 3 Shift in positive striation position as a function of time. 30 watt mercury vapor tube @ 25 ma direct current. Time measured by phase shift of light output signal with respect to the anode signal.

C. Negative Striations

Several authors[4, 7] have reported the existence of negative striations with motion directed away from the cathode. At least one experimental paper has reported their notable absence.[6]

Examination of mercury-vapor devices in thisstudyhas shown the presence of positive striations, but no conclusive experimental evidence has been found to demonstrate the existence of negative striations. A rotating mirror has failed to detect them. However, it should be noted that difficulty would be encountered in detection with a rotating mirror if the striation velocity were to exceed several hundreds of meters per second. The rotating mirror used in this study was able to detect striations moving up to only 200 - 300 meters per second.

An oscillographic method as shown in Fig. 2 was employed with two wires capacitively coupled to the plasma. A signal of amplitude adequate to trigger the oscilloscope was obtained. No time shift in the signal could be detected for different spacings between the two pickups. Since the circuit could measure a striation velocity of magnitude up to 5×10^4 meters per second, the possibilities remain that either there exists a negative striation of phase velocity greater than 5×10^4 meters per second or there exists a periodic distubbance such that the entire positive column is disturbed uniformly in time, which corresponds to an infinite phase velocity.

The second oscillographic method by which the oscilloscope is synchronized with a signal from the tube anode and the photomultiplier output is presented on the vertical input was also used. Here a weak light signal (less than 10 per cent amplitude of the positive striation) was noticed to be superimposed on the light signal due to the positive striation. Motion of the photomultiplier along the tube revealed that this small light signal remained fixed on the oscilloscope time base. The net result was the same, either the small signal was due to a disturbance occurring throughout the tube simultaneously, which corresponds to an infinite phase velocity, or the disturbance moved with a very great phase velocity.

The minute size of this signal would account for the inability of a rotating mirror to detect it.

D. Variation in Electrostatic Signal Along the Tube

It was noticed that the signal from an electrostatic pickup varied in strength periodically as a function of distance along the positive column. Very sharp null points were found at which the electrostatic signal strength dropped to a very low value. See Fig. 4.

This phenomenon was particularly pronounced if the electrostatic pickup signal was filtered so as to pass only the fundamental frequency of oscillations of the tube. The signal strength on the average declined with detector motion towards the cathode.

These results would tend to indicate the existence of both positive and negative striations by the hypothesis that the null points are fixed points in space where the two types of striations meet. The decline of the signal strength with motion towards the cathode would be expected if the losses in the striation due to recombination were slightly greater than gains due to ionization between meeting points. It is assumed that the two types of striations represent two different polarities of space-charge clouds.[4] If we follow the hypothesis of Donahue and Dieke[4] that there exists two types of striations, one which upon reaching the cathode (or anode) end of the tube releases one of the opposite type, then it can be shown easily that they pass each other at fixed points in space.

For example, choose some point of origin near the anode for the positive striations and assume they release negative striations from some point near the cathode. See Fig. 5.

Consider the striations as infinitely thin sheets of charge Q_1, Q_2. Let the separation between positive striations be L_1 and the separation between negative striations be L_2. Then the position of the first positive striation is given by

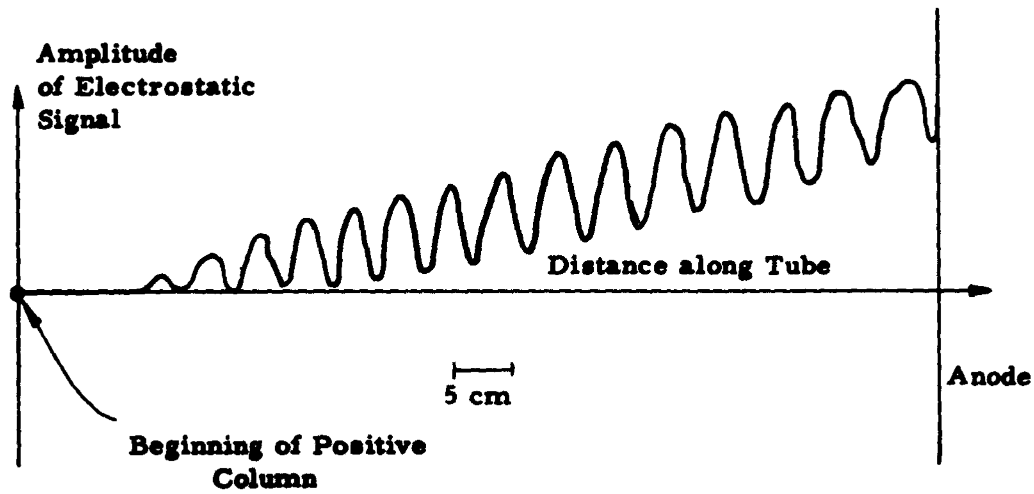

Fig. 4 Fundamental component of electrostatic signal amplitude vs distance along discharge tube. 30 watt mercury-vapor lamp @ 50 ma tube current. Frequency of oscillation is 1100 cps.

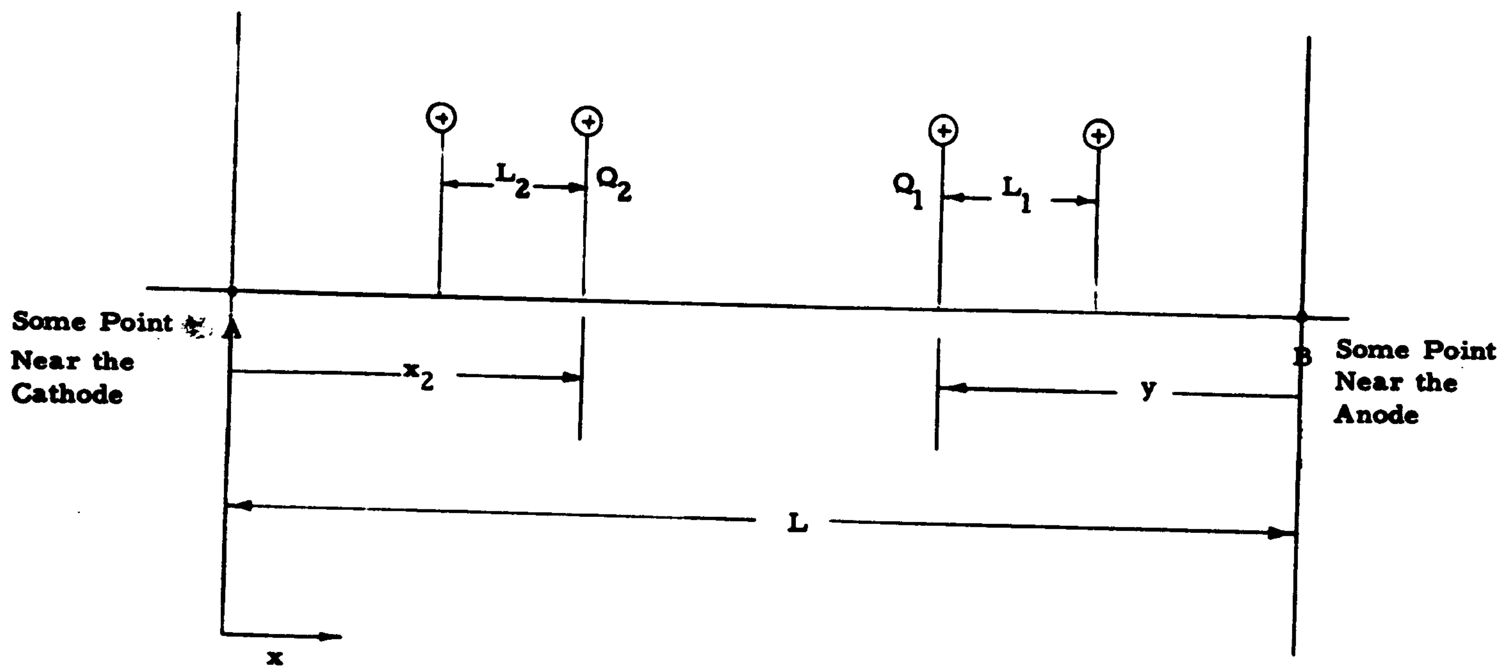

Fig. 5 Simplified representation of moving striations in a mercury-vapor plasma.

$$X_1 = L - Y = L - v_1 t \qquad (1)$$

where v_1 is the velocity of motion of the positive striation.

Assuming now that a negative striation is released when $X = 0$, it is seen that the time between successive releases of negative striations is

$$t_o = \frac{L_1}{v_1}. \qquad (2)$$

Thus the separation of negative striations becomes

$$L_2 = v_2 t_o = \frac{L_1 v_2}{v_1} \quad , \qquad (3)$$

where v_2 is the velocity of motion of the negative striation.

For positive striations, an equation of motion relating position of the nth positive striation to time is

$$X_{1n} = L + (n-1)L_1 - v_1 t \qquad (4)$$

where $t = 0$ when the first positive striation leaves the point of origin B. Similarly, an equation for negative striations is

$$X_{2m} = v_2(t-t_1) - (m-1)L_2 \qquad (5)$$

for the mth negative striation, where t_1 is the time necessary for the first positive striation to travel the distance L from B to A.

$$t_1 = \frac{L}{v_1} \quad .$$

Points in space where the striations meet are defined by the equation

$$X_{1n} = X_{2m} \qquad (6)$$

Substituting equations (4) and (5) into (6), we get

$$L + (n-1)L_1 - v_1 t = v_2(t-t_1) - (m-1)L_2 \tag{7}$$

$$L + (n-1)L_1 - v_1 t = v_2\left(t - \frac{L}{v_1}\right) - (m-1)L_2 \; . \tag{8}$$

Substituting equation (3) and regrouping,

$$(v_1+v_2)t = \frac{L(v_1+v_2)}{v_1} + (n-1)L_1 + (m-1)\,\frac{L_1 v_2}{v_1} \tag{9}$$

simplifying,

$$t = \frac{L}{v_1} + L_1\,\frac{v_1(n-1) + v_2(m-1)}{v_1(v_1 + v_2)} \quad . \tag{10}$$

Position X of the meeting points can be found by substituting (10) into (4).

$$X = L + (n-1)L_1 - L - L_1\left(\frac{v_1(n-1) + v_2(m-1)}{(v_1 + v_2)}\right) \; . \tag{11}$$

$$X = (n-m)\,\frac{L_1 v_2}{v_1+v_2} \; . \tag{12}$$

Equation (12) shows the positions of intersection of striations of different types to be fixed points in space separated equally by a distance

$$d = \frac{L_1 v_2}{v_1+v_2} \; . \tag{13}$$

Note that if v_2 is much greater than v_1 then d is on the order of L_1. This has been found to be the case experimentally in mercury-vapor tubes. The distance L_1 is determined from the frequency of tube oscillation and measured striation velocity. L_1 is found to be approximately also the distance between null points of a graph of electrostatic pickup signal versus position along the tube.

These results along with negative striation velocity measurements would tend to support the Donahue and Dieke[4] hypothesis for the existence of two types of moving striations. This would be subject to the condition that it could be conclusively shown that what has been observed here is in fact a negative striation of high phase velocity or even infinite phase velocity. It is noteworthy that Donahue and Dieke[4] report negative striation velocities on the order of 1,000 meters per second.

E. Effects of ac Excitation on the Devices

A rather vivid demonstration of the existence of positive striations is obtained when an alternating voltage is applied to mercury-vapor tubes (here G.E. germicidal lamps). The devices are operated here in a cold cathode manner, in which case they are symmetrical except for possible slight differences in the electrodes. The applied ac ionizes the tube in one half cycle and establishes discharge conditions such that positive striations are started in motion. The next half cycle's tube potential tends to move the striations in the reverse direction. The net optical result is that the positive column appears to be segmented into a string of glowing beads separated by small dark spaces. A rotating mirror clearly shows the individual striation motion back and forth.

A more complete demonstration of the back and forth motion of a positive striation is shown by Fig. 6. This figure shows oscillograms of the photomultiplier output for various positions of the photomultiplier along a single stationary striation. Starting in a dark space between striations, Fig. 6a, the photomultiplier is moved along the striation in increments equal to one-eighth of the striation length, Figs. 6b-6i. The applied ac was approximately 0.7 milliamperes at a frequency of 1500 cycles per second. The tube examined was a 30 watt G.E. germicidal lamp.

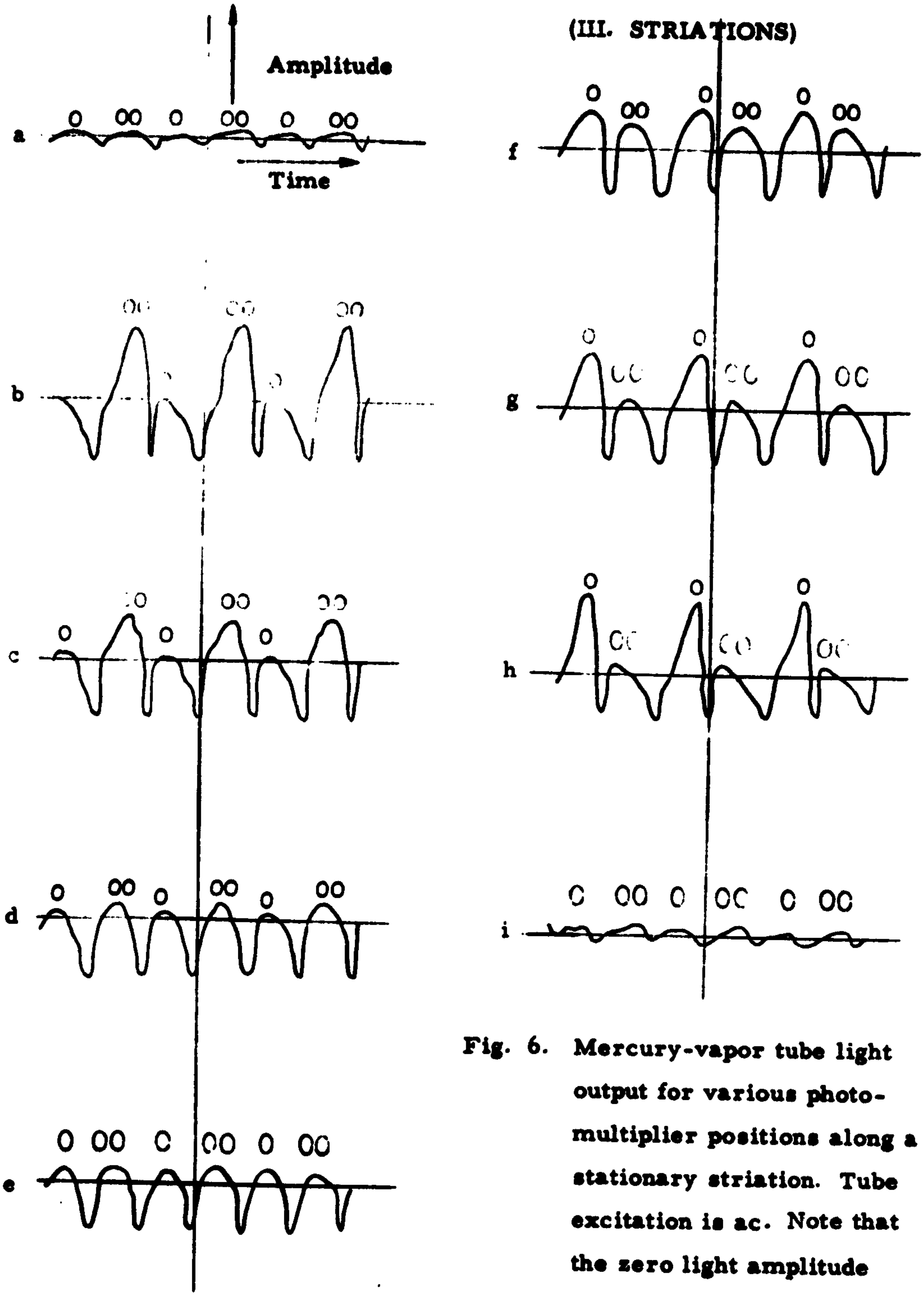

Fig. 6. Mercury-vapor tube light output for various photomultiplier positions along a stationary striation. Tube excitation is ac. Note that the zero light amplitude axis is suppressed.

Oscillograms 6a - d are very similar to oscillograms 6i - f as would be expected by considerations of symmetry. Graphs 6b, c, d show one light output peak increasing in amplitude with motion of the photomultiplier toward the striation center (the peak marked with a dot). Graphs 6b, c, d also show one light output peak decreasing in amplitude with motion toward the striation center (the peak marked with two dots). At the striation center (Fig. 6e), each peak is of the same amplitude.

As the photomultiplier is moved away from the striation center to the other end (Figs. 6f, g, h), it is seen that the singly dotted peak continues to increase in amplitude while the doubly dotted peak continues to decrease in amplitude.

Thus it is seen that each light peak represents the same positive striation in a different half cycle of the applied ac. The singly dotted peak in Fig. 6b shows the positive striation starting its motion toward one end of the tube and the doubly dotted peak shows the same striation returning toward the end of the next half cycle. Each succeeding oscillogram shows the singly dotted peak decreasing in amplitude with motion along the tube while the doubly dotted peak increases in amplitude as the origin of its half cycle motion is approached.

During the second and fourth quarters of a cycle of an impressed sinusoidal voltage, the voltage value declines. Thus, crudely speaking, a decline in tube current and striation light output with time might be expected to occur during part of the moving striation's cyclic journey. Note this in Figs. 6b to 6h for the doubly dotted light peak.

A rotating mirror shows that the moving striation spends a majority of its time at the ends of the stationary striation. This correlates well with oscillograms 6b and 6h which show a sizable time lag between the weak light peak and the strong one, thus indicating that the striation moves very little during the time that the ac is passing from one half cycle to the next.

The use of ac in a manner that yields a stationary striation pattern could be very useful in studying the relation of striation amplitude and velocity to tube current and potential drop. Such an analysis has not been conducted here, so further detailed interpretation of Fig. 6 is not feasible.

Parameters such as pressure, frequency, and tube current must be such that each individual striation does not lose its identity from one half cycle to the next. If this were not the case, a stationary striation pattern might not be seen.

This phenomenon has been reported earlier[8] with the statement that it was observed to occur at approximately the frequency at which the tube oscillated intrinsically under dc discharge conditions. We note here, however, that this phenomenon is observable at frequencies other than frequencies near the intrinsic oscillation frequency or its harmonics. For example, see Fig. 7. Here the discharge tube studied was a G. E. 5 watt germicidal lamp. Discharge current was kept at a low value so that tube current and potential drop were essentially sinusoidal for convenience in measurement. The length of the stationary striation in this case was 3 centimeters and was constant over the frequency range 900 to 19,500 cycles per second. There is only a higher order dependence of current on frequency for striations to be held perfectly stationary. A larger or smaller current value than that plotted in Fig. 7 will cause the stationary striation pattern to drift down the tube in one direction or the other with a small velocity of a few centimeters per second.

The stationary striation pattern is remarkably distinct. See Fig. 8, a photograph for the 5 watt tube at the 3.7 kc point on Fig. 7.

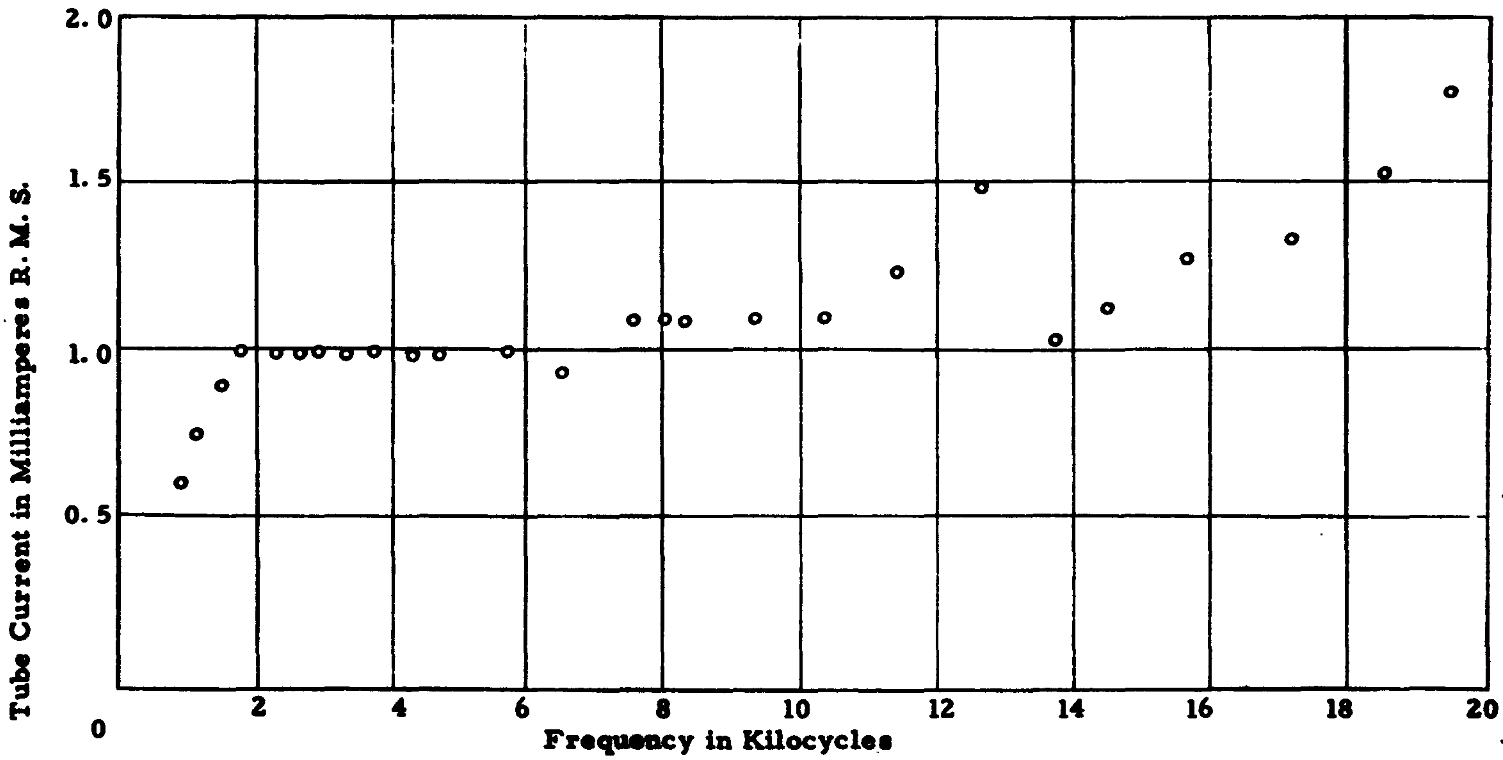

Fig. 7 Ac tube current at which stationary striations are observed in mercury-vapor as a function of frequency. 30 watt G. E. germicidal lamp employed.

For various other yet unexplored conditions, one or more stationary striations with ac excitation are often seen to divide into two distinct stationary striations. Also two adjacent striations are observed to coalesce into one. When the striations are seen to drift slowly down the tube, both of these processes can be observed to occur at once. Division occurs at one end of the tube, putting striations into the moving stream. Combination occurs at the other end of the tube, removing striations from the moving stream.

F. Stationary Striations in Ultrapure Hydrogen

At pressures in excess of a few microns in the hydrogen filled pure gas device, a very distinct stationary striation was noted to occur under direct current input conditions. Oscillographic and rotating mirror examinations failed to reveal the presence of any type of moving striations. Also, time-periodic oscillations were conspicuously absent. In most cases, the stationary striation was stable enough and distinct enough to be photographed. See Fig. 9.

Oscillations did occur in a transient fashion, however, whenever the stationary striation pattern was observed to become indistinct. A rotating mirror revealed this condition to be a vibratory motion of the entire striated positive column. The column appeared to move approximately a striation's length back and forth, giving a total movement of roughly two centimeters.

Considerable difficulties in studies with the hydrogen device were encountered due to instability. This is possibly the result of a rapid drift in internal hydrogen pressure.

Fig. 8 **Photograph of stationary striations for an ac excited 5 watt G. E. germicidal lamp.**

Fig. 9 **Photograph of stationary striations in the dc excited ultrapure hydrogen tube.**

IV. CONCLUSIONS

No conclusive statement is obtainable yet regarding the question of the existence of oscillations and striations in ultrapure gases. We note here that work has been done[9] where striations and oscillations have been obtained in helium. However, with the pure gas device employed here, no such phenomena have been observed.

To date, published reports have been somewhat contradictory regarding the existence of negative striations. From the above series of experiments, we conclude that if the negative striation does exist in the same form as the positive striation, then it travels with a very high velocity. Since there does exist indirect evidence for its existence and since velocity measurements have failed to measure a finite velocity, we can only conclude that there is also the possibility that the observation is not of a negative striation as such, but of a closely related phenomenon.

Positive striations, on the other hand, have been observed to be very well defined experimentally and quite easy to measure. The weight of evidence would appear to overwhelm any question as to the existence of these striations.

By the observations made of perfectly stationary striations in an ac driven mercury-vapor device, it is found that the device is not particularly "resonant" at the frequency of intrinsic oscillation of the dc discharge. A stationary striation pattern is easily obtainable for a wide continuous range of frequencies in which the intrinsic oscillation frequency is included. The oscillograms of the photomultiplier output for various positions of the photomultiplier clearly show that each stationary striation in the ac case is the optical result of back and forth motion of a moving positive striation.

Unfortunately, the oldest known type of striation and most observed, the stationary striation under dc excitation, has been seen only in one type of gas in this study. It can be said definitely that such a phenomenon does occur in ultrapure hydrogen, but the matter remains incompletely understood.

It is tempting to speculate that the striation velocity (where a velocity exists) is equal to the velocity of a sound wave, or something similar to a sound wave in a gas. The observed velocity of positive striations in mercury-vapor is very close to 50 meters per second. Stationary striations where a frequency exists would also allow a velocity to be calculated. Unfortunately, no case of the latter was found in the gases observed. The velocity of sound in a gas depends on two things, the molecular weight and the temperature. The question arises as to what temperature to use. If the electron temperature (e.g., 30,000 deg. K.) is used, the calculated velocity is far too high; if the positive ion temperature (e.g., 3,000 deg.) is used, the calculated velocity is still much too high; if the neutral gas temperature (e.g., 300 deg.) is used, the calculated velocity is only about a factor of 2 too high. Perhaps the striation velocity is the velocity of sound in the neutral gas modified by wall effects. If so, this raises the question of how the charged particle motion is coupled to the neutral molecule motion.

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Electronics Research Directorate, Air Force Cambridge Research Laboratories, Office of Aerospace Research, U.S. Air Force, Bedford, Mass.
Rpt. No. AFCRL-63-25, POSITIVE-COLUMN STRIATIONS IN GASEOUS CONDUCTORS
Interim Report, June 62, 26p., incl. illus., 11 refs.

Unclassified Report

The positive column in certain gaseous conductors was examined by external electrostatic probe pickup, by photoelectric signal pickup, and by rotating mirror images for time-periodic oscillations and space-periodic striations. Mercury vapor with dc excitation gave moving positive striations (motion away from anode) of large amplitude with a velocity of about 50 meters per second. No direct observational evidence of negative striations was found, contrary to what has been reported by some authors, but there was some indirect evidence of weak negative striations. No stationary striation pattern was found in mercury vapor with dc excitation. Mercury vapor with ac excitation gave pronounced stationary striations, which were found to be the optical result of cyclic motion of a sequence of moving positive striations. Ultrapure hydrogen and helium were examined. No oscillation or striation phenomena were found in these gases with the exception of a pronounced stationary striation pattern in ultrapure hydrogen under dc excitation.

1. Electron Tubes
2. Plasma Physics
I. AFCRL Project No. 5634, Task No. 563402
II. Contract AF 19(628)-324
III. Univ. of California, Berkeley, Calif.
IV. Dobrats, B. E.
V. ERL Series No. 60, Issue No. 454
VI. Aval for OTS: $1.25
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